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Application of Multiple Criteria Decision Models for Oilseed Crops in Pakistan's Punjab

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INTRODUCTION

Pakistan is deficient in major food products. Self-sufficiency in food has virtually always been a major priority, because imports of wheat, edible oil, sugar, pulses and milk products put a massive burden on the balance of payments for the country. The increase in the production of oilseed has been a priority goal of the agricultural development policy in Pakistan.

The oilseed crops have been validated as alternative crops on several target locations of different agro-ecological zones [PARC (1990)]; but the success of this validation work in terms of their dissemination is very limited. The possibility of including these crops in well established systems needed to be well conceived. The selection of farming systems, which have the potential to adopt such crops, is a prerequisite to investigate the problems and prospects of oilseed crops.

The emphasis of the study is, therefore, on the identification of typical farm situations where the oilseed crops can be evaluated for their potential inclusion in the cropping plans. A real decision-making environment in agriculture involves several objectives along with their explicit targets. Hence, farmers' behaviour cannot be adequately explained in terms of a single criterion of maximisation of profit. Thampapillai and Sinden (1979) indicated that a single monetary objective in past decisions was mainly dominant as a result of problems in the measurement of non-money value effects. The several methodological studies [Ignizio (1978); Romero (1985); Buchanan (1986); Romero *et al.* (1988); Romero and Rehman (1984); Romero and Rehman (1985); Rehman and Romero (1993)] and some empirical studies [Thampapillai and Sinden (1979); Flinn *et al.* (1980); Sankhayan *et al.* (1988); Berbel (1989); Manos (1991); Piech and Rehman (1993)] conducted by

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considering multiple objectives and farmer's goals highlight the importance of this perspective in generating farm level feasible plans. It has been argued in these studies that multiple objectives are the rule in farm planning, the single objective is an exception. This seems to be the case whether the decision-maker is a farmer or a policy-maker [Romero and Rehman (1989)]. In this study, the farm-planning problem handled by employing the analytical methods of the Multiple Criteria Decision-Making (MCDM) paradigm.

The Specific objectives of the study are:

(i) To elicit the importance given to a range of objectives by a representative sample of farmers in the 'rice-wheat' and 'cotton-wheat' zones of the Punjab;
(ii) To build Linear Programming and Goal Programming (and its selected variants) models (MCDM) to analyse the economic implications of the adjustments of alternative crops in the cotton zone of Pakistan's Punjab;
(iii) To draw broad implications from the study for research, extension and agricultural policy.

DATA COLLECTION AND ANALYTICAL METHODS

In the selection process farming systems where oilseed crops were already being cultivated were selected. It was presumed that successful adjustments of these crops in certain farming systems could help to understand the problems and prospects of their expansion at the same or other localities. Vehari as high oilseed producing districts from cotton-wheat farming systems of the Punjab province was chosen for this study. Selection of 6 sample villages and 70 respondents were accomplished in multiple visits to the sample district. The questionnaires were designed especially by considering the local references of storing and expressing information on the planning and management aspects of farms. The specific statements on current farm planning objectives were differentiated from general orientation of farmers towards their farming business.

The sequential analytical framework used in this study to build MCDM models at farm levels. First, the typification of farms was undertaken through numerical analysis of the farms as subjects. The typological variables were filtered through attitudinal variables to identify more realistic and dynamic representative farm situations. Cluster Analysis (CA) was used here to classify farms according to their similarity. Second, the 6 farm and family objectives were analysed to establish goal hierarchies and weights. The resulting typologies were then used to construct representative farm models in study zones. Base models of typical farms using linear programming techniques were developed which were later converted into their MCDM equivalent versions.

The lexicographic and weighted goal programming (LGP and WGP) are the two obvious MCDM methods where goal hierarchies and weights can be used in a straightforward manner; thus the WGP method has been selected for this study to use precise target values and weights that are relevant to the representative farm situations. Romero and Rehman (1989) point out that a decision-making problem of a modest level of 6 objective dimensions can be easily accommodated within the GP framework. The GP modelling approach is therefore, taken as the method to model the complex nature of the decision-making situations prevailing at representative farms.

THE EMPIRICAL RESULTS

Selection of Representative Farms

It is difficult to describe or comprehend fully the diversity of agricultural systems. Simplification for analysis is a practical necessity and it is also essential to simplify for an effective communication with agricultural practitioners [Marten (1988)]. Sebillote (1996) indicated that for development actions it has been necessary to identify a few groups of production units that are homogeneous enough to produce diagnoses and to develop solutions and references for extension. The idea of recommendation domains is also in use for more efficient targeting of recommendations [Byerlee *et al.* (1980)]. It is being established that when systems are too large or too complex to study in their entirety, subsystems may be identified which can be used separately [Mettrick (1993)].

The representative farms were decided on the basis of their similarity to the average farm situations of each cluster of the two production zones. The similarity between the average farm and the observed farm was computed through the total distance between both, defined as the sum of the squared standardised difference between every variable of the farm and its group average.

The variability accounted for in the classificatory variables has the added advantage of ensuring the independence between the number of types retained. Perrot and Landais (1993) also recommend avoiding all purpose variables which are inevitably poorly adapted to cope with situational diversity. The distances between average and observed variables were computed for all the subsets of farms present on each cluster of the two production zones. Within each cluster the farm with the lowest aggregate distance was selected as a representative farm for building the MCDM models. Table 1 shows the partial and total deviation of a selected farm from its corresponding average farm.

Table 1

Partial Standardised Deviations and Total Squared Deviations from the Clusters Averages for All Selected Farm

Production Systems	Cotton Zone			
Clusters	I	II	III	IV
Farms Identification	A	B	C	D
Manager's Age	0.28	1.08	–0.27	0.31
Manager's Education	–0.71	–0.83	0.42	0.06
Manager's Farming Experience	0.44	1.20	–0.61	0.85
Farm Equipment	–0.72	1.31	–0.80	0.02
Operational Holding	–1.03	0.75	–0.28	–0.63
Loamy Soils				
Off-farm Income	–0.55	–1.12	–0.58	0.80
Livestock Units Per Ha	0.84	1.58	–0.88	0.68
Area Allocation to New Crops				
Permanent Hired Labour Hours	–0.36	0.39	–0.17	–0.53
Family Labour Hours	0.01	1.15	–1.03	0.52
Total	3.48	10.83	3.55	2.87

Estimation of Targets for Goals

The targets for the farm planning goals of the representative group of farms are derived from the data collected about the aspirations of farmers to improve their farming business. The targets of leisure goals are calculated for number of hours per day or the number of additional days per month a farmer wants to take-off. The debt financing or debt avoidance targets were estimated from the aspirations expressed by farmers, such as: (a) to reduce the present level of farm debts; and (b) the desire to borrow the amount that was needed to meet the working capital requirements of the next production cycle. The inventory enhancement targets were calculated from the aspirations of farmers to make the fullest use of operational land in terms of fixed farm resources. The hiring targets of farm resources (land, labour and equipment) were calculated from the present rate of the seasonal hiring to perform important farm operations. Employment of family labour on farm or off-farm was estimated by calculating: (a) the number of additional man days of family labour a typical farmer wants to employ on farm; or (b) the number of family members he wants to spare for off-farm employment opportunities. The family subsistence targets are estimated by calculating the minimum family food requirements both for quantity of farm output and minimum area allocation to achieve these output targets. The profitability targets are estimated by calculating the additional area a farmer wants to allocate to new enterprises or the increase in the productivity of existing enterprises he wants to achieve. The increment in the production of new and conventional enterprises aspired for estimated as the profitability targets of the farm planning decisions.

Specification of Single and Multiple Criteria Models

The modelling starts by building single criterion basic linear programming models to analyse the planning problem from the point of view of the general perceptions of the National Research System (NRS). These models then incorporate the system interactions and limitations, as they exist in reality, on the selection of alternative crop activities. Such versions of the basic models are christened Realistic Linear Programming (RLP) models here. Finally, the *a priori* absolute preferences of the DMs are used to convert the RLP models into their WGP versions. The stepwise improvement in the base LP models are considered to analyse the outcomes of these models with the existing beliefs and practices of the DMs working at research, extension and policy level. These alternative farm modelling approaches would provide an opportunity to assess how much the actually observed plans are deviating from the proposed plans.

The Objective Function in the Base Lp, Rlp, and Wgp Models

The objective function of the base LP models reflect the main decision criterion used at policy and research levels. It is presumed that the prime goal of farmers in their farm planning decisions is to obtain as high an annual income as possible and this is reflected in maximisation of total gross margin (GM) from various farming and non-farming activities. The decision variables such as alternative crop activities, labour hiring, capital borrowing and irrigation water hiring activities generate positive or negative activities for the objective function depending on weather they represent returns or costs. In total fifteen crop activities included in the base models comprise the complete range of alternative crop enterprises that farmers select from in the cotton-wheat zone.

The objective function in the realistic linear programming (RLP) models consists of additional activities of buying, selling and consumption activities. The selling activities are included for all crop enterprises whereas, buying activities were included for food and fodder crops only. The activities specified for RLP models have been disaggregated in order: (a) to have flexibility for making adjustments to the objective row coefficients for testing various hypothesis; and (b) to reduce or detect the chances of errors in specifying interactions among technical and economic coefficients of the models.

The achievement function in the GP model is formulated as the sum of deviations between the achievement of pre-specified goals and their targets. The farm planning goals are specified in the achievement function of the GP models as the minimisation of negative (d^-) or positive (d^+) deviations which symbolise under-achievement or over-achievement of each goal, respectively. The six objectives in the achievement function of the GP models are specified as 'maximising' or 'minimising' goals. For the maximising goals negative deviations are minimised and vice versa for the minimising goals. The six objectives that have been specified are:

(i) maximise family food requirements;
(ii) minimising/maximising casual labour hiring;
(iii) maximising fixed farm resources of family labour, permanent hired labour and seasonal land utilisation;
(iv) maximising farm profits;
(v) minimising working capital borrowing; and
(vi) minimising/maximising area allocation to new crops.

The deviational variables in the achievement function of a GP model are measured in different units. For instance, labour is measured in hours, crop area in hactares, profit and capital borrowing in rupees, quantity of food consumed in monds. The deviational variable coefficients are therefore given in percentage deviations to overcome the problem of incommensurability of units by using the following manipulation, where t_i represents target value for goal i:

$$\sum_i \frac{1}{t_i}(d_i^- + d_i^+)$$

The deviations are weighted according to the relative importance of each goal as required for the typical decision-making situations (see Table 2). The desirability

Table 2

Weights for Goals of the Representative Farms of the Cotton and the Rice Zones of Pakistan's Punjab

Objective	Cotton Zone			
Titles	RFS-A	RFS-B	RFS-C	RFS-D
Subsistence	400	15	43	75
Employment	733	16	14	17.5
Technologies	800	70	200	250
Leisure	40	36	64	225
Borrowing	467	79	143	200
Inventory	100	100	100	100

of goals is indicated through minimising a specific set of negative or positive deviations. So, the expression becomes:

$$\sum_i \frac{1}{t_i}(w_i^- d_i^- + w_i^+ d_i^+)$$

Where w_i^- and w_i^+ represent the goal weights relevant to each representative farm situation.

The Matrices of Farm Planning Models

The base LP matrices are constructed for RFS to highlight the differences in the observed and predicted crop plans based on the single objective of profit maximisation. The matrices used in this analysis are of a moderate size (i.e. 55 rows and 51 columns) portraying the conventional production constraints of land, labour, capital, irrigation water and traction power. The additional resources (capital, labour and irrigation water) can be acquired in these models at the local market rates. No restrictions were imposed on the acquisition of these resources.

The structure of the base LP models where many functions were combined under a single activity were transformed into a set of disaggregated activities as RLP models, increasing the size of the matrix to 72 columns and 107 rows. The constraints used in these models are similar to the base LP models except that the resources use limits on labour hiring, capital borrowing and the choice of new crop enterprises were built as additional restraints. These limits on new crops highlight the risk aversion behaviour and crop diversification motives of the representative groups of farmers.

The matrices of RLP models are transformed to WGP models by introducing: (a) two deviational variables for each planning goal to convert an inequality into an equality; and (b) the conversion of resource availability limits into targets in accordance with the aspirations of the representative groups of farms. The RHS elements of the equalities of the GP models are specified as targets which may or may not be achieved. The WGP model is a 130 column (68 columns of real activities and 62 deviational variables) and 103 resource row matrix.

The Results of the Base LP Models

The results of the base LP models of the four RFSs are presented in Tables 3 and 4. The actual crop plans and the plans predicted through single criterion optimisation models are presented together. The results show that during *kharif* season area allocation to cotton is at par both in the observed and model crop plans. The only difference is that model prefers growing cotton early rather than late and the same applies to wheat.

Table 3

Comparison of the Observed Plans and the Model Solutions for the Representative Farm Situations in the Cotton Zone

Activities	RFS-A			RFS-B		
	Observed Plan	Model Solution	Change	Observed Plan	Model Solution	Change
GM (Rs)	63,007	1,21,817	61,122	4,34,259	7,22,594	2,88,335
Clay Loam Soil			Area in Hectares			
Wheat-timely	0.81	0.81	–	3.24	1.62	–1.62
Wheat-late	0.81	–	–0.81	8.90	–	–8.9
Cotton-early	0.40	2.08	1.68	2.42	13.76	11.34
Cotton-late	1.21	–	–1.21	9.71	–	–9.71
Sunflower	–	1.27	1.27	–	12.14	12.14
Maize	–	–	–	–	–	
Mustard	–	–	–	0.20	–	–0.2
Sugarcane	0.20	–	–0.2	1.21	–	–1.21
Pepper	0.20		–0.2	0.40	–	–0.4
Sorghum	0.40	0.34	–0.06	1.21	1.21	
Berseem	0.40	0.34	–0.06	0.81	1.21	0.4
Silt Loam Soil						
Cotton-early	–	–	–	–	–	–
Sunflower	–	–	–	–	–	–
Cropping Intensity*(%)	191	200		188	200	12
Farm Size (ha)	2.43	2.43		14.97	14.97	

* Total cropped area (*Rabi* season + *kharif* season)/operational size of holding.

Table 4

Comparison of the Observed Plans and the Model Solutions for the Representative Farm Situations in the Cotton Zone

Activities	RFS-C			RFS-D		
	Observed Plan	Model Solution	Change	Observed Plan	Model Solution	Change
GM (Rs)	3,83,135	5,04,704	1,21,569	4,61,487	8,21,340	3,59,853
Clay Loam Soil						
Wheat-timely		1.21	–0.81	4.04	1.62	–2.42
Wheat-late	2.02	–	–2.02	8.09	–	–8.09
Cotton-early		7.39	7.39	2.02	14.16	12.14
Cotton-late	6.48	–	–6.48	10.12	–	–10.12
Sunflower	4.05	6.18	4.15	–	12.55	12.55
Maize	–	–	–	0.40	–	–0.4
Mustard	–	–	–	–	–	–
Sugarcane	–	–	–	–	–	–
Pepper	–	–	–	–	–	–
Sorghum	0.81	0.71	–0.1	2.43	2.02	–0.41
Berseem	0.81	0.71	–0.1	2.43	2.02	–0.41
Silt Loam Soil						
Cotton-early	2.02	2.02	–	–	–	–
Sunflower	2.02	2.02	–	–	–	–
Cropping Intensity*(%)	180	200	20	183	200	17
Farm Size (ha)	10.12	10.12	0	16.19	16.19	0

* Total cropped area (*Rabi* season + *kharif* season)/operational size of holding.

The wheat crop is replaced substantially by sunflower in the optimum solutions of the representative farms. The model plans propose more than 50 percent area allocation to sunflower crop for the *rabi* season. The area allocation to other new crops like sugarcane, pepper, maize, mustard and lentil crops is non-existent in the model solutions. The sunflower and cotton crops grown for commercial purposes dominate the plans of the *rabi* and the *kharif* seasons respectively. The cropping intensity for the model plans increases to 200 percent indicating that two crops are grown on the same piece of land in two consecutive seasons during the year. The model solutions conform exactly in the way the research and extension system advocate the timely cultivation of these crops should take place.

The Results of the RLP Models

The results derived from realistic linear programming models indicate the cautious attitude of farmers in committing scarce farm resources to adopt new technological innovations. Farmers are generally more cautious in the adoption of a package of technology rather than the component technologies of a package. The rapid adoption of the B-385 rice variety and slower adoption of sunflower, soybean and mustard are the recent examples of such adoption phenomenon observed in Pakistan [Sharif *et al.* (1989); Shafiq *et al.* (1990); Ministry of Food and Agriculture (1995)].

From the 'new' crops sugarcane, sunflower and mustard crops entered in the RLP model solutions. Relatively, higher proportion (46 percent) of land was allocated to sunflower in the model solution of RFS-C as compared to the other farm situations. The area allocation to sunflower crop is reduced considerably in the RLP model plans as compared with the LP plans, resulting in more area being allocated to normally and late planted wheat. The restriction on the traction power to plant timely cotton crop and the capital and labour limits for sunflower production are the main reason behind these changes in the proposed plans of the RLP models.

The Goal Programming Models

The results derived from the GP models reflect the interaction effect of real constraints on farm resources and the crop planning objectives of the representative farms. In the WGP model for the RFS-A, RFS-B and RFS-C situations the under-achievement of 'land use', 'gross margin', and 'family food' goals are minimised. The over-achievements are minimised for 'labour hiring' and 'capital borrowing' goals. For the RFS-D situation the over-achievement of the 'new crop technologies' goal is minimised. These alternative crop-planning situations are examined through running WGP models and the results are presented in Tables 5–8.

Table 5

Comparison of the RLP and the WGP Model Solutions for the Representative Farm Situations in the Cotton Zone

Activities	RFS-C Observed Plan	RFS-C Model Solution	RFS-C Change	RFS-D Observed Plan	RFS-D Model Solution	RFS-D Change
GM (Rs)	1,07,139	97,725	–9,414	4,97,990	4,84,381	–13,609
			Area in Hectares			
Wheat-timely	1.11	1.12	0.01	6.87	7.27	0.4
Wheat-late	0.47	–	–0.47	4.87	0.41	–4.46
Cotton-early	1.11	1.11	–	6.87	6.87	–
Cotton-late	0.87	0.40	–0.47	5.27	2.84	–2.43
Sunflower	0.40	0.40		0.40	2.02	1.62
Maize	–	–	–	–	–	–
Mustard	–	–	–	–	2.02	2.02
Sugarcane	0.03	0.25	0.22	1.62	1.62	–
Pepper	–	0.25	0.25	–	0.40	0.4
Sorghum	0.41	0.41	–	1.22	1.22	–
Alfalfa	0.41	0.41	–	1.22	1.22	
Silt Loam Soil	–	–	–	–	–	–
Wheat-timely	–	–	–	–	–	–
Cotton-early	–	–	–	–	–	–
Sunflower	–	–	–	–	–	–
Cropping Intensity(%)	197.1	200	2.9	189.2	200	10.8
Farm Size (ha)	2.43	2.43	–	14.97	14.97	–

Table 6

Targets and the Levels of Achievement of Farm Planning Goals in the WGP Models of the RFSs in the Cotton Zone

Labour Months	RFS-A Target Level	RFS-A Solution Value	RFS-A Change	RFS-B Target Level	RFS-B Solution Value	RFS-B Change
			Family and Permanent Hired Labour (Hours)			
May	518	361	–30%	1012	706	–30%
June	518	152	–71%	1012	166	–83%
July	518	342	–34%	2024	1235	–39%
October	518	410	–21%	1012	782	–23%
November	518	187	–64%	1012	584	–42%
December	518	24	–95%	1012	324	–68%
January	518	17	–97%	1012	305	–69%
February	518	67	–87%	1012	371	–63%
March	518	18	–96%	1012	218	–78%
April	518	98	–98%	1012	444	–56%
			Casual Hired Labour (Hours)			
May	–	–	–	2426	1215	–50%
June	–	–	–	1200	678	–43%
July	–	–	–	1200	352	–71%
October	–	–	–	1440	1175	–18%
November	–	–	–	720	599	–17%
December	–	–	–	117	0	–100%
January	–	–	–	62	0	–100%
February	–	–	–	32	160	+400%

Table 7

Targets and the Levels of Achievement of Farm Planning Goals in the WGP Models of the RFSs in the Cotton Zone

Particulars	RFS-A Target Level	RFS-A Solution Value	RFS-A Change	RFS-B Target Level	RFS-B Solution Value	RFS-B Change
			Capital Borrowing (Rs)			
Dec.-Feb.	13487	13487	0	38610	0	–100%
March-May	–	–	–	66288	0	–100%
June-August	13010	12956	–0.4%	58302	0	–100%
Sep.- Nov.	–	–	–	–	–	–
			Area Allocation to New Crops (Ha)			
Sunflower	0.40	0.40	0	2.02	2.02	0
Maize	–	–	–	–	–	–
Mustard	–	–	–	2.02	2.02	–
Sugarcane	0.25	0.25	0	1.62	1.62	0
Lentil	–	–	–	–	–	–
Pepper	0.25	0.25	0	0.40	0.40	0
			Land Use (Ha)			
Rabi Season	2.43	2.43	0	14.97	17.97	0
Kharif Season	2.43	2.43	0	14.97	14.97	0
			Food Crop (Ha)			
Wheat	1.50	1.50	0	2.41	7.68	+218%
			Gross Margin (Rs)			
Total	120000	107777	–10.19%	550000	484382	–11.9%

Table 8

Comparison of the RLP and the WGP Model Solutions for the Representative Farm Situations in the Cotton Zone

Activities	RFS-C RLP Solution	RFS-C WGP Solution	RFS-C Change	RFS-D RLP Solution	RFS-D WGP Solution	RFS-D Change
GM (Rs)	4,49,587	4,79,402	29,815	5,87,879	5,96,669	8,790
Wheat-timely	3.41	1.42	–1.99	7.43	7.43	–
Wheat-late	–	–	–	5.79	4.98	–0.81
Cotton-early	4.64	4.64	–	7.43	7.43	–
Cotton-late	2.48	2.98	0.5	6.42	6.42	–
Sunflower	3.65	5.14	1.49	0.63	0.63	–
Maize	–	0.41	0.41		0.81	0.81
Mustard	0.41	0.47	0.06	0.32	0.32	–
Sugarcane	–	–	–	–	–	–
Pepper	–	–	–	–	–	–
Sorghum	0.85	0.85	–	2.02	2.02	–
Alfalfa	0.85	0.85	–	2.02	2.02	–
Silt Loam Soil	–	–	–	–	–	–
Wheat-timely	0.37		–0.37	–	–	–
Cotton-early	1.17	1.17	–	–	–	–
Sunflower	0.80	1.17	0.37	–	–	
Cropping Intensity(%)	184.1	193.0	8.9	198.02	198.02	–
Farm Size (ha)	10.12	10.12	–	16.19	16.19	–

The RFS-A situation represents the majority of the small farmers in the cotton zone who want to have stable income through crop diversification. The sugarcane and pepper crops appear in the WGP solution as a result of higher weights assigned by the farmers to the ‘new crop technologies’ goal (Table 5). The model substituted both late sown wheat and cotton crops area by new crops. The GM in the WGP plan is reduced by up to 10 percent when compared to the single criterion RLP model. The cropping intensity increased to 200 percent. The targets of ‘land use’ and the area allocated to ‘new crops’ and ‘food crops’, are achieved fully (Tables 6 and 7). The targets for hiring labour were not specified in this model, as the farmers use family labour for all types of work on farm. The family labour is also surplus in all periods. It was used to the maximum extent of 70-80 percent in May, July and October periods. The capital borrowing targets in two critical demand periods (December-February and June-August) are fully met.

The RFS-B represents the large farmers’ situation who are in a transition stage. In the GP model solutions, the area under late sown cotton and wheat is replaced by sunflower and mustard crops. The higher weights assigned by the farmers to ‘capital borrowing’ and to ‘land use’ goals are the main reason behind these alterations. Hence, more crop diversification is found in the solutions obtained through GP model. There is no capital borrowing in all three high capital demand periods in the WGP solutions (Table 7). The cropping intensity has also increased by 10 percent in the GP solutions as compared to the RLP ones. The area allocation target for the new crops and the land use intensity targets have been achieved exactly. The regular and the hired labour use targets are under-achieved for most of the labour demanding periods. In order to implement the GP solution 160 hours of hired labour are required in February to implement the GP model solution.

The area allocated to wheat is more than twice what is required for meeting the family food targets. Only the timely planted wheat activity is selected in the GP solution for the family needs and for selling the surplus in the market.

The RFS-C model represents the farm situations where farmers are really interested in trying out the new crop technologies, either in component or in package form. The WGP plans of this farm situation reflect the new crops oriented planning goals and aspirations of the farmers. There is no area allocated to late sown wheat both in the RLP and the WGP models. About half of the area allocated to timely planted wheat is also replaced by new alternative crops (Table 8).

The maize crop is also included in the WGP crop planning solution. The area allocated to sunflower increased on both types of land. The planning solutions of the WGP models are more crop intensive than the RLP model plans. About 7 percent increase in GM could be achieved by implementing the GP model plans as compared with the RLP plans. The ‘capital borrowing’ target set for December to February period was met exactly (Table 10).

No borrowing is required to be made for the March-May and June-August periods. The land use intensity target is under-achieved by 6 percent and 5 percent for the *rabi* and *kharif* seasons, respectively. The target set for the wheat as a food crop is slightly surpassed. The targets of area allocation to sunflower and mustard crops are over-achieved by 41 percent and 15 percent respectively. Similar to the other farm situations the regular labour use targets were under-achieved considerably (Table 9). The hired labour requirements are over-achieved by 6 percent for the October and November period. The GM target is under-achieved by 4 percent.

The RFS-D is a typical farm situation where farmers follow mainly the predominant cropping system of the area. A majority of these farmers are risk averse and are not very interested trying out new crop enterprises requiring additional skills and in certain cases specialised production resources as well. The sunflower planter implement is an example, which is required to sow hybrid sunflower seed at proper depth and at uniform distance. The new crop technologies are used as minimising goal in the GP model of the RFS-D situation.

Table 9

Targets and the Levels of Achievement of Farm Planning Goals in the WGP Models of the RFSs in the Cotton Zone

	RFS-C			RFS-D		
Labour Months	Target Level	Solution Value	Change	Target Level	Solution Value	Change
			Family and Permanent Hired Labour (Hours)			
May	624	166	–73%	952	835	–12%
June	624	396	–36%	952	342	–64%
July	1248	417	–66%	1904	1640	–13%
October	624	512	–18%	952	1081	13%
November	624	197	–68%	952	446	–53%
December	624	30	–95%	952	176	–81%
January	624	150	–76%	952	126	–87%
February	624	247	–44%	952	105	–89%
March	624	119	–81%	952	83	–91%
April	624	117	–81%	952	83	–91%
			Casual Hired Labour (Hours)			
May	1209	382	–31%	1724	1545	–10%
June	840	477	–43%	1541	1507	–2%
July	840	429	–51%	666	634	–5%
October	856	907	6%	1723	1641	–5%
November	488	453	6%	861	821	–5%
December	59	0	–100%	–	–	–
January	62	0	–100%	–	–	–
February	320	486	51%	115	115	0

Table 10

Targets and the Levels of Achievement of Farm Planning Goals in the WGP Models of the RFSs in the Cotton Zone

Particulars	RFS-C Target Level	RFS-C Solution Value	RFS-C Change	RFS-D Target Level	RFS-D Solution Value	RFS-D Change
Capital Borrowing (Rs)						
Dec.-Feb.	35725	35725	0	119736	17189	2.13%
March-May	79343	0	–100%	–		
June-August	46182	0	–100%	103285	94329	–8.7%
Sep.- Nov.	–	–	–	–	–	–
Area Allocation to New Crops (Ha)						
Sunflower	4.45	6.31	42%	1.61	0.63	–62%
Maize	0.41	0.41	0	0.81	0.81	0
Mustard	0.41	0.47	16%	0.81	0.32	–60%
Sugarcane	–	–	–	–	–	–
Lentil	–	–	–	–	–	–
Pepper	–	–	–	–	–	–
Land Use (Ha)						
Rabi Season	10.12	9.47	–6.4%	16.19	16.19	0
Kharif Season	10.12	9.65	–4.7%	16.19	15.88	–2%
Subsistence Crop (Ha)						
Wheat	1.10	1.42	0.29%	8.0	12.41	55%
Gross Margin (Rs)						
	50000	479402	–4.1%	625000	596668	–5%

The model solution reflects the deliberate attitudes of farmers towards the inclusion of new crops in their farm plans. The maize crop is included in the plan with a partial replacement of area allocated to late wheat crop (Table 8). The total GM of the WGP plan is 2 percent higher than the RLP plan with some minor crop adjustments. The higher weight attached to minimising the goal of capital borrowing could be the possible reason for this adjustment in the WGP model plan.

The target set for the sunflower and mustard crops are under-achieved in the solution by more than one half of a percent (Table 10). The target set for wheat crop is over-achieved by 55 percent. The capital borrowing and the labour hiring targets are slightly under-achieved. The achievement of the targets of regular farm labour are considerably under-achieved during the November-April period (Table 9). However, their use is quite high when compared to the May-October period. The regular hired labour use target is over-achieved by 13 percent during October. Although regular hired labour is surplus during most of the time in a year, but the scarcity of casual labour during peak demand periods indicates farmers' rationality to hire labour on an annual basis.

CONCLUSIONS AND RECOMMENDATIONS

The use of the LP, RLP and WGP models highlighted the differences in the solutions of the single criterion and multi-criteria farm planning models. The result of LP models shows how idealistically the decision-makers at research and policy level think that their objectives can be achieved. The results from the RLP models represent the optimum crop plans under the realistic resource use situation of the representative farms. The WGP models provide solutions that are closer to the planning goals and aspirations of the farmers.

The results obtained from the WGP models are closer to the real resource situations and the planning goals of the representative groups of farms. The casual labour hiring and the capital borrowing minimising targets are fully achieved for all of the farm situations. The minor adjustments in the crop plans resulted into a considerable decrease in the use of scarce farm resources at critical times. Borrowing of capital is fully eliminated in the WGP solution of the RFS-B situation, which accounts at quite a high level, in the LP and RLP solutions. This activity is also reduced or confined to one critical demand period for other situations as well. The GM is slightly reduced for the first two farm situations and increased for the rest of the representative farms. The soft restraints of the WGP model have provided useful information about the additional labour resources required to implement the proposed crop plans of the model. The differences in the goal weights and the targets of the representative farm situations are reflected in the level of the inclusion of sunflower and mustard crops in the model solutions. More area is allocated to oilseed crops on those farms, where either there is the previous experience of growing this crop or there is interest in crop diversification. On the other hand less area is allocated to oilseeds on specialist farms.

The representative farm situations, where oilseed crops are not currently included in the crop plans, can be used for developing strategies for future promotion of the oilseed crops by the agricultural research and development system. The framework of analysis validated in the cotton-wheat system could be replicated more rigorously for the same or other potential farming systems. The methods can be used to explore the adjustment potential of other candidate crops (oilseed and pulses) on representative farm situations for diverse ecological conditions. Specific knowledge about crop planning decisions ought to be generated to facilitate decision-making at research, policy, extension and farm levels.

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Comments

The paper under reference is a pioneer effort in applying sophisticated linear programming techniques, MCDM that is commonly found in literature. This approach uses multi-attribute utility theory, search for Pareto optimal solutions via multicriteria linear programming, heuristic search methods and goal programming [Eppen and Gould (1987)].

This paper offers decision-making tools for farmers and policy-makers in agriculture production with reference to Punjab's agriculture. After critically reviewing the paper I offer few suggestions according to my understanding and knowledge.

The overall organisation is lacking. There are no explicit assumptions. Abstract does not include any result that a reader should see at the outset. Key words are missing. The models and variables are not fully explained along with reference. There are abbreviations through out the text. These need elaboration. A thorough review of literature is required. It will be more appropriate if full background of the problems is given long-with justification in the introduction part. Why the area was selected and why MCDM were preferred? Similarly, the procedure of development of representative farms across farm categories needs explanations. It is difficult to find a representative situation in farming over a vast geographic region. It is suggested that hypothetical farms based on situation prevailing in particular area and expert opinion with respect to available fixed resources, technical coefficients and other related information is developed for different farm categories. The objectives should be included in the last part of introduction instead of result section.

It is not understood why analyses dropped rice-wheat area? This is an important area that originally is part of this study. As pointed out earlier models are not explicitly given. Resultantly, the variables are not clearly defined. Weighted goal programming (WGP) models are applied in the study. But, the data are not appended. For example, there is need to specify numeric goals; one ended and or two ended goals. A careful selection is again needed for the type of goal programming i.e., preemptive or nonpreemptive. Penalties for missing a target level of objectives are also not assigned.

The empirical results section (p. 517) is elaborative. However, it needs organisation. Pages 515-516 are in fact subject of either introduction or analytical methods. The results given in Tables 4 and 5 provide information in representative farm situations. However, if it is further discussed with relevance to the over achievements, under achievement and or exact achievement of a goal it will be more informative. Product substitution and risk and uncertainty involved under model plan be also considered and included in analysis. References are not arranged in alphabetical order. The effort of authors will provide useful guideline to decision-making agents for choosing alternate farm plans under representative farm situation.

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